The design and realization of interaction region for BEPCII

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IHEP

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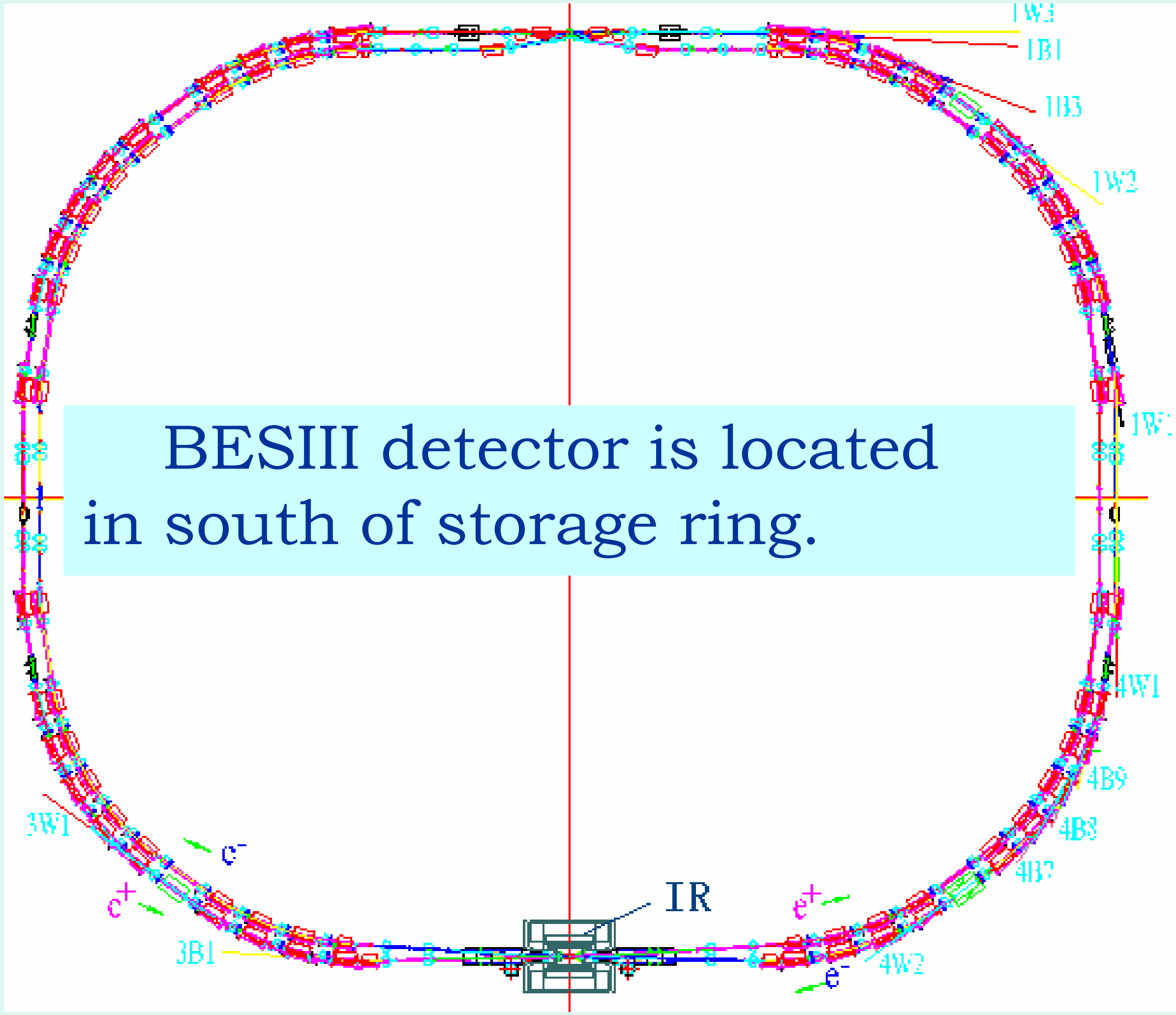
- **Layout of the IR**
- **Special magnets**
- **Compensation of detector solenoid**
- **Synchrotron radiation**
- **Vacuum chamber**
- **Collision tuning monitors**
- **Supporting system**
- **Summary**

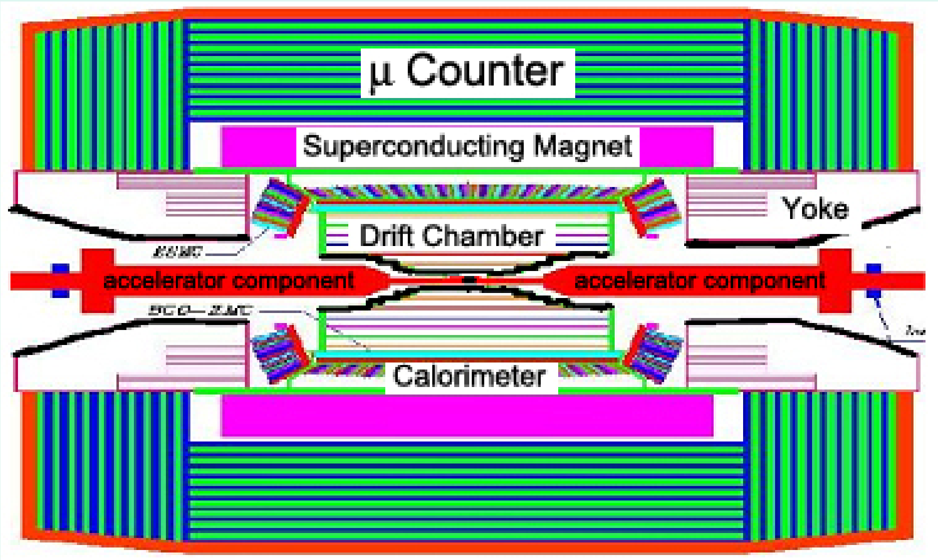
Layout of the storage ring



BESIII detector is located in south of storage ring.

Interface between machine and detector

The geometry of the drift chamber requires accelerator components inside the detector must fit within a conical space with an opening angle of 21.5°.



With restricted outer diameter, the first accelerator element can only approach to 0.552 m on each side of the IP.

Side view of the BESIII detector and SC final focusing magnet

Beam Line layout in the IR

Beam separation scheme for colliding mode

- **A horizontal crossing angle of 11 mrad × 2 at the IP**

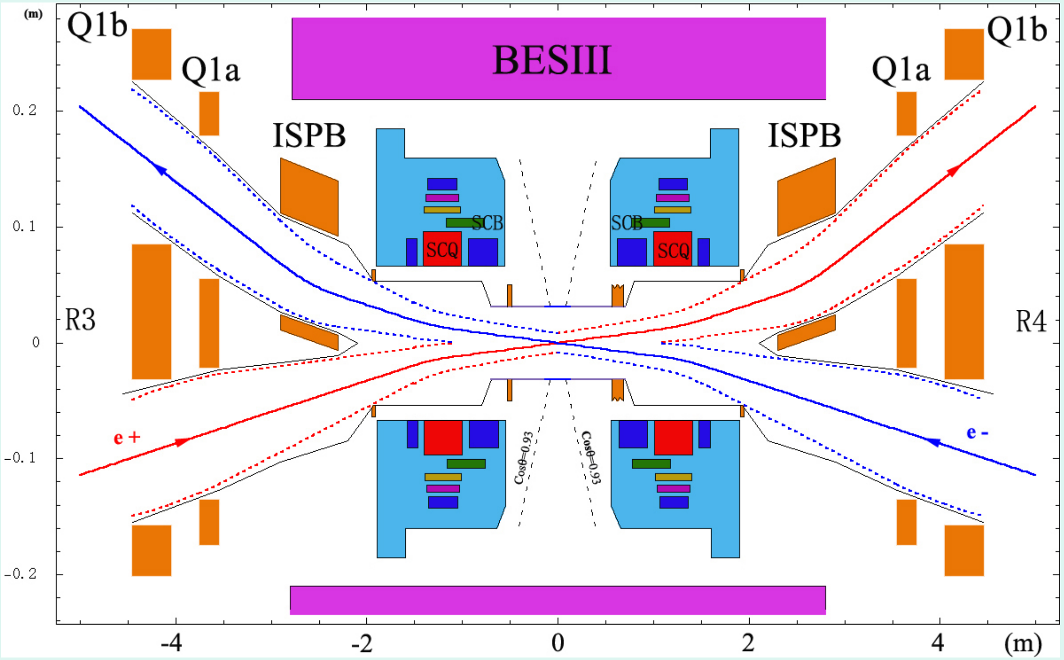
  A reasonable value from the consideration of IR length(-14m~14m), the effects on parasitic beam-beam interaction and piwinski angle.

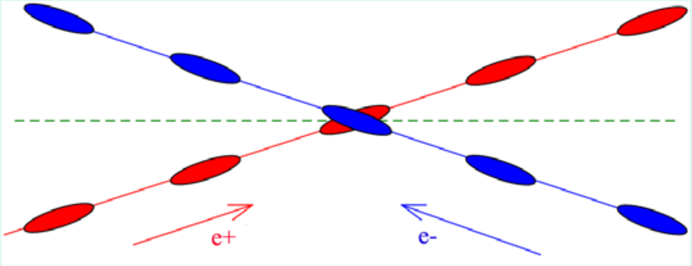
- **Off-Center SC quadrupole.**

  Shared by two beams, deflect the beams further to 26 mrad × 2.

- **Septum bending magnet ISPB.**

  Only deflect the beams in the inner ring to 65.5 mrad.

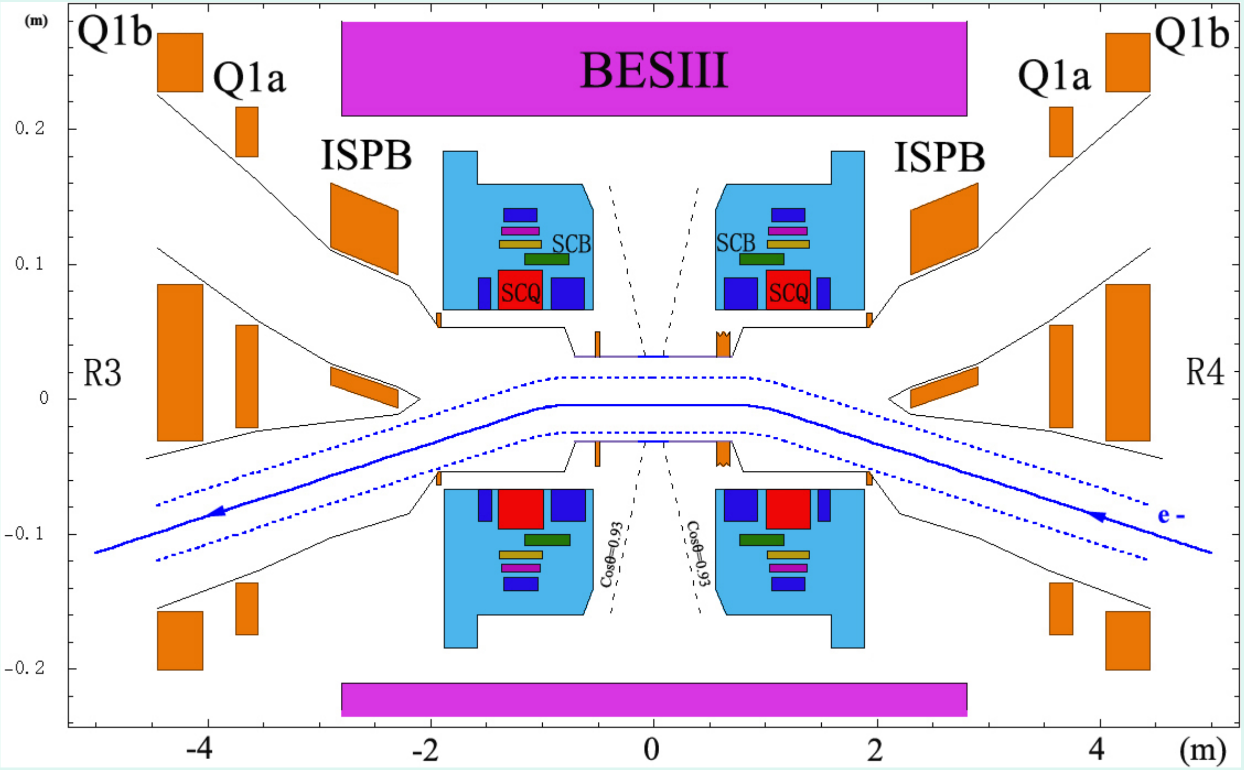




Beam Line layout in the IR

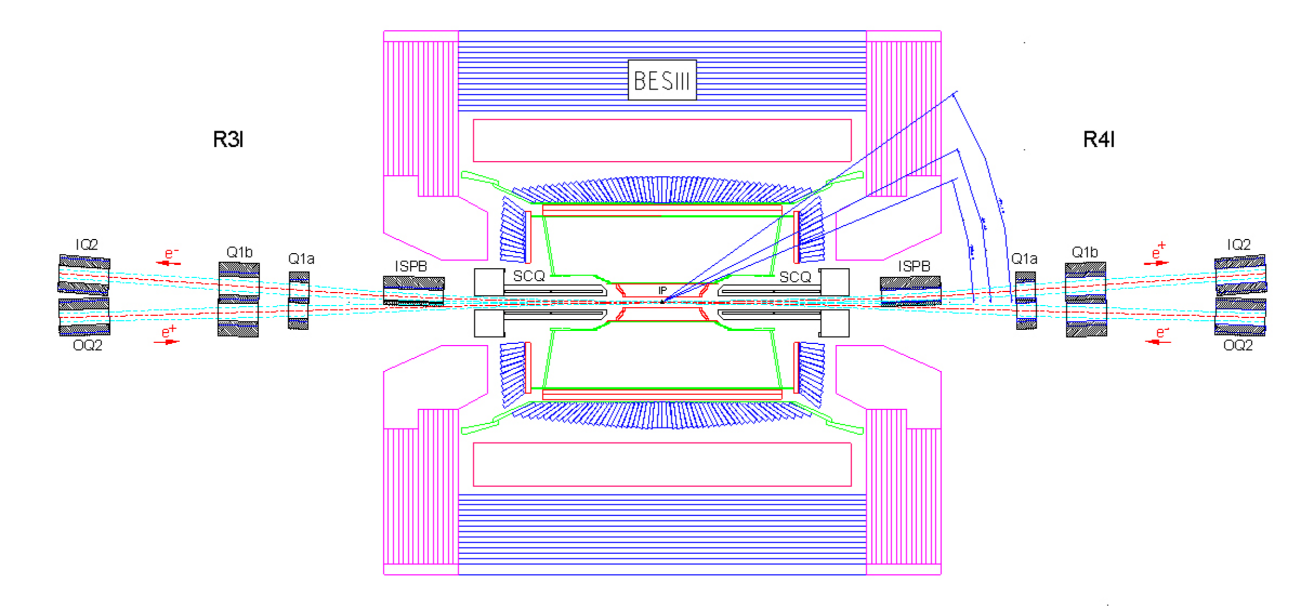
Survey design for SR mode

- **BEPCII is also designed for synchrotron radiation application.**
  The switch of two modes is to control the power supplies of SCQ and SCB. The bending dipoles SCB connect the outer-ring.
  During SR mode operation two SCQs are turned off.



Beam Line layout in the IR

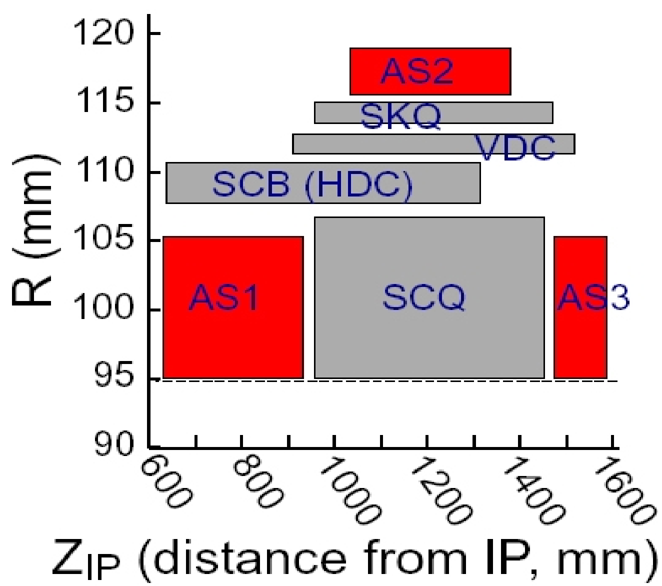
A doublet of quadrupoles for final beam focusing



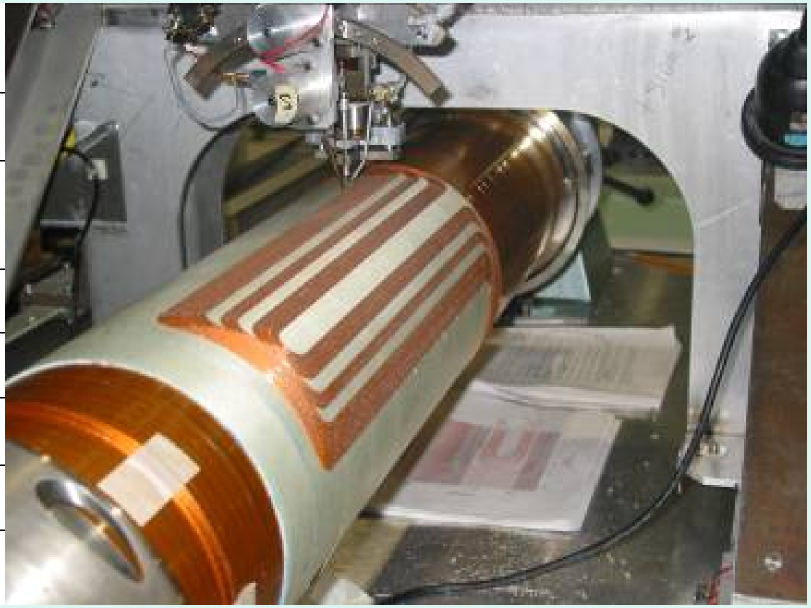
- Doublet of quadruples SCQ, Q1 provides the final focusing.
- The vertical focusing quadrupole SCQ is a superconducting magnet shared by both beams. The horizontal focusing quadrupoles Q1a and Q1b are designed as a compact two-in-one structure.

Special magnets in the IR --- SC magnet

Coil winding layout of superconducting magnet



Name	Layers
SCQ	8
SCB (HDC)	2
VDC	2
SKQ	2
AS1	6
AS2	2
AS2	6



Design and fabrication of the SC magnets are the key for IR design. The main mechanical work of SC magnets was completed in China and the main coils were wound at BNL laboratory in U.S.

AS1~3: Anti-Solenoid, **SCQ:** Quadrupole, **SCB:** Dipole magnet

SKQ: Skew quadrupole, **VDC:** Vertical steering magnet

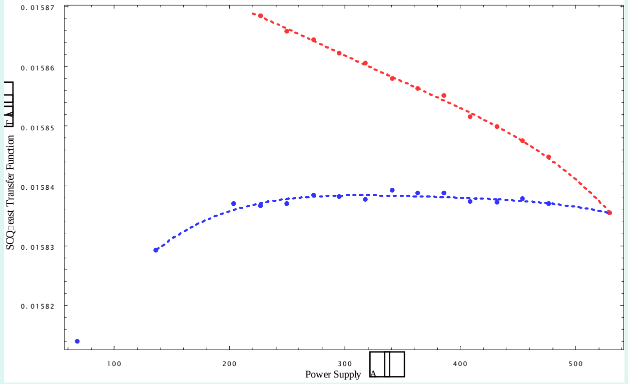
Special magnets in the IR --- SC magnet

Field measurements of SC coils

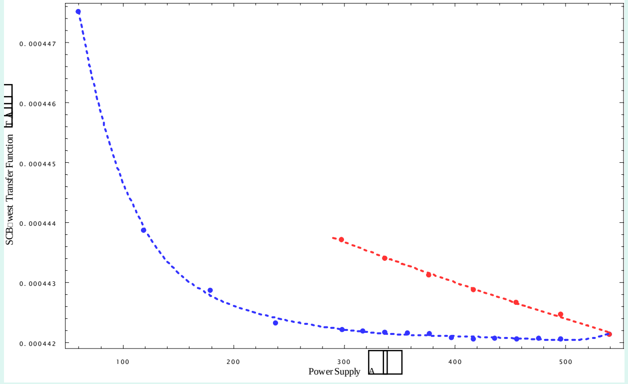
SCB (R=38mm) $B_n/B_1<5\times10^{-4}$
SCQ (R=50mm) $B_n/B_2<3\times10^{-4}$

The field measurements of detector solenoid, anti-solenoids, SCQ, SCB, HDC, VDC and SKQ have been performed at IHEP.

- The harmonic components were measured by the **rotating coil system**.
- The integral gradient, offset and tilt angle were measured by **stretch wire**.
- **Salamander system** was used for measurements of the longitudinal field created by detector solenoid and anti-solenoids.



Transfer function of SCQ



Transfer function of SCB

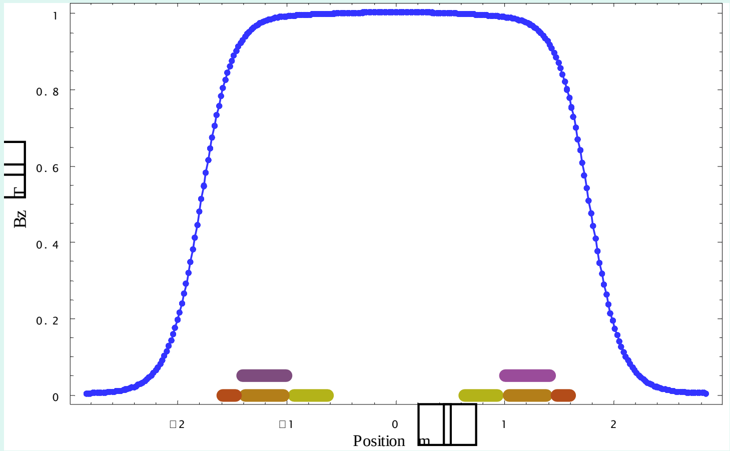
East SCQ : Larger sextupole component of 7.0×10^{-4}. Other components are ok.

Other coils: The field quality can satisfy the requirements.

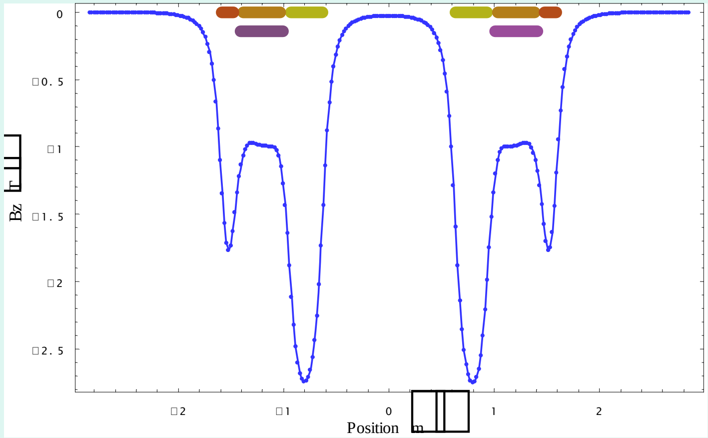
Coupling compensation scheme in the IR

Solenoid and anti-solenoids

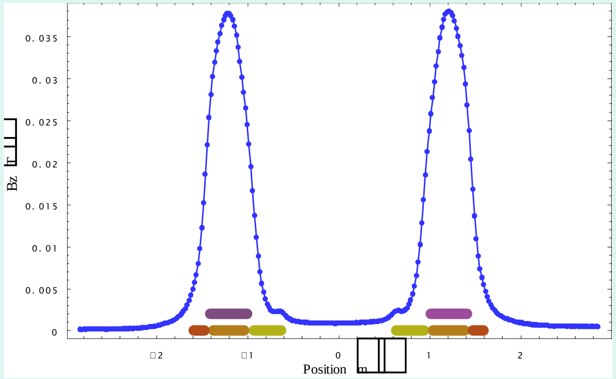
AS2 and AS3, which have their own independent trim circuits, are in series with AS1.



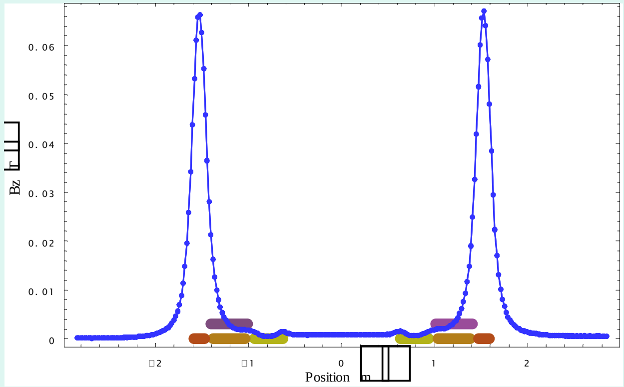
detector solenoid



AS1



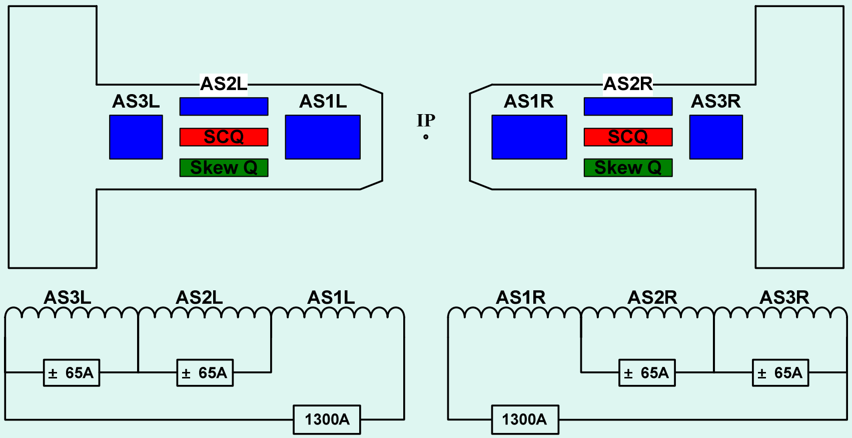
AS2

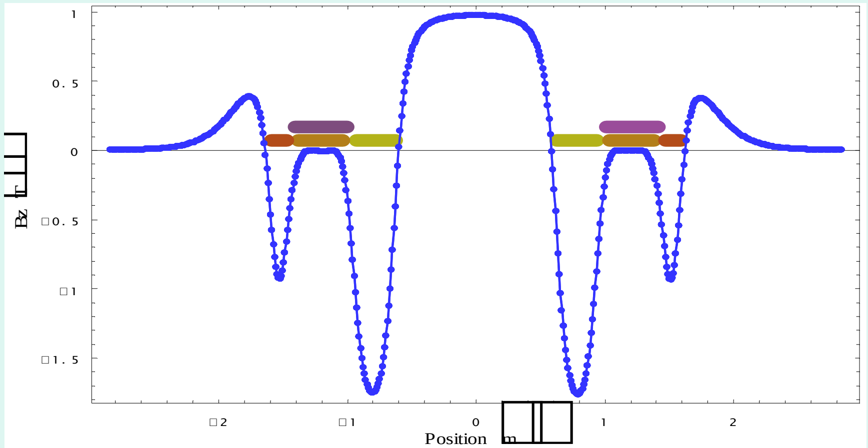


AS3

Coupling compensation scheme in the IR

- Detector solenoid (1.0 T & ±1.8m) is the dominant coupling source.
- Collider will be operated at the energy range of 1.0GeV to 2.1GeV .





Three anti-solenoids (AS1~3) and a skew quadrupole are used to compensate the detector field locally. This compensation can work perfectly for particles with any momentum.

∫Bzds between the IP and the SCQ is zero. Bz over the SCQ is nearly zero. ∫Bzds after the SCQ is zero too.

Skew quadrupoles are used to make fine tuning over the SCQ region instead of the mechanical rotation.

Special magnets in the IR --- ISPB

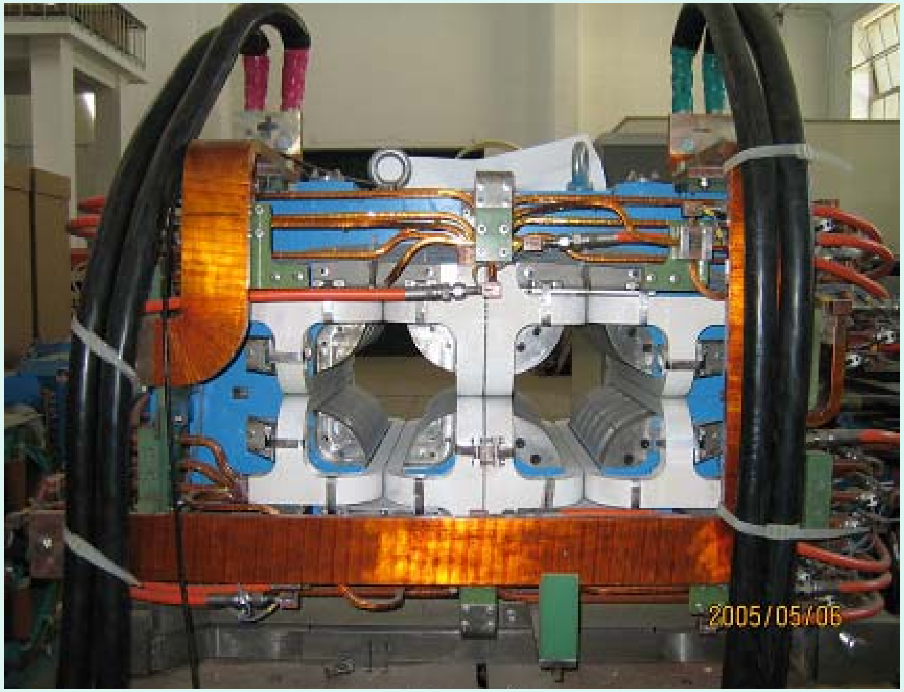
The septum bending magnet ISPB has a narrow septum coil of 16.4mm (beam separation is 26mm) and only acts on the outgoing beam line.

With this magnet, the outgoing beams are deflected about 39 mrad. This provides a separation between the two beams at 3.55 m from the IP, which **is possible to place a special quadrupole**.

ISPB is located at 2.3m from the IP, inside the detector gate, immersed in the fringe of the detector solenoid field. A field clamp plate at the inboard end of the magnet is used to shield off the detector field.

Its performance meets the requirements of $B_n/B_1 < 5 \times 10^{-4}$

Special magnets in the IR --- Q1a Q1b



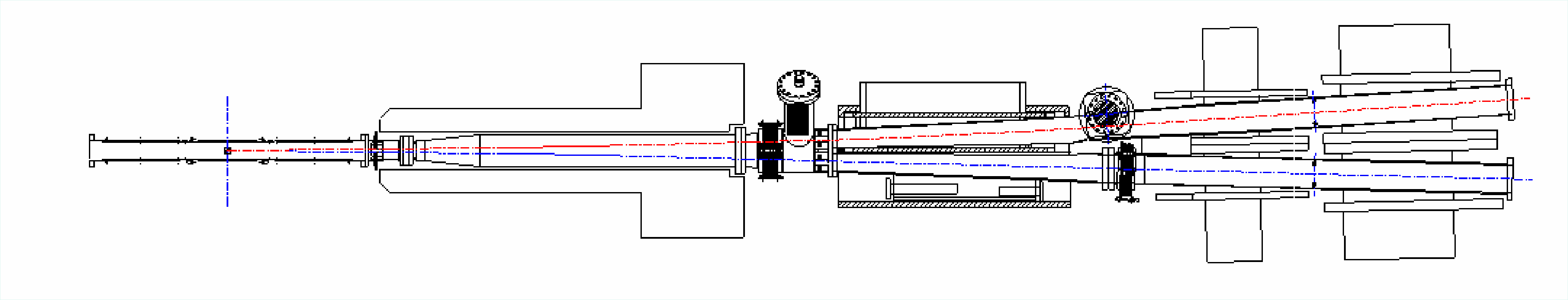
Q1a $B_n/B_2<4\times10^{-4}$ @ R=53.5mm **Q1b** $B_n/B_2<2.5\times10^{-4}$ @ R=61.5mm

Q1 is located at 3.55m from IP where beam separation is only 9cm. We have to divide it into two magnets Q1a and Q1b to make device realizable. They are designed as a compact two-in-one structure which the two beam apertures are in a common yoke.

Field quality satisfy the requirements of beam dynamics

Vacuum chamber in the central IR

Mechanical design



- The central part is Be pipe with the length of 0.3m and inner diameter of 63mm.
- The Be pipe is welded to a copper cylinder with the length of 0.35m and inner diameter of 63mm.
- Except Be pipe, the material of vacuum chamber within ±3.5m is chosen as copper for its low coefficient of photon-induced gas adsorptions, large photon absorption coefficient and high thermal conductivity.

Vacuum chamber in the central IR

The most complicated part---Crotch chamber

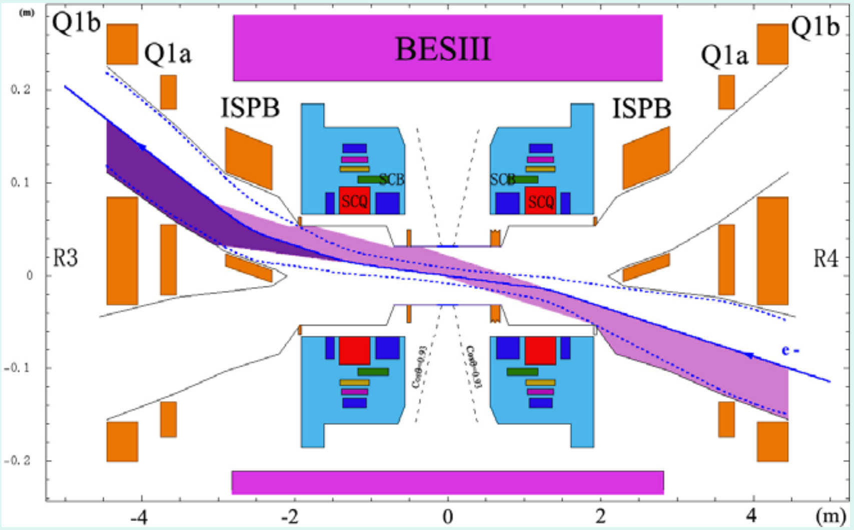
The crotch chamber is ~0.3 m long in which a bellows, one NEG pump, water cooling system and two BPMs are installed.

SR=220W, HOM=1000W

Water cooling system can control the temperature rise of body within 50 ^{o}C with the maximum heat power. (Operation experience)

Vacuum chamber in the central IR

Background --- Synchrotron radiation photons



SR fans of Colliding Mode

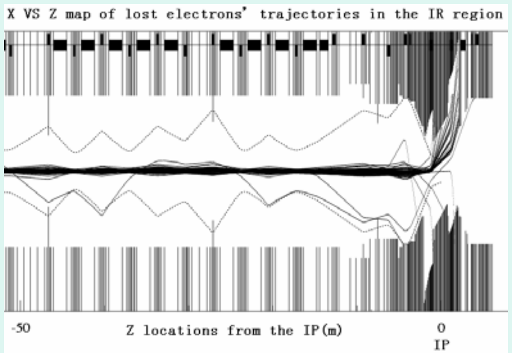
For IR design, it's very difficult to stop both direct and once-scattered photons emitted within $10\sigma_x$ of beam size at all magnets hitting on the detector beryllium pipe.

0.5W of SR power contributed by both e+ & e- beams will hit directly on the beryllium pipe. Ec<1.2keV

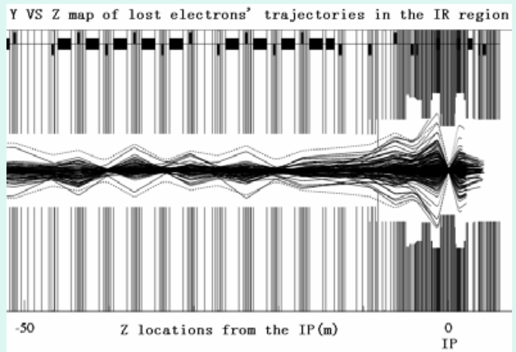
In order to absorb as much as possible SR photons which penetrates the IP chamber into the detector, about **10μm gold** layer was sputtered inside the inner beryllium cylinder. **The simulation shows that photon background is low enough.**

Vacuum chamber in the central IR

Background --- Lost Particles

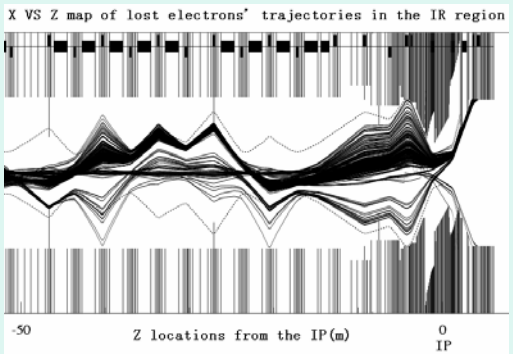


bremsstrahlung



Coulomb scattering

Beam-Gas Interactions



Touschek effects

Trajectories for lost particles (with masks)

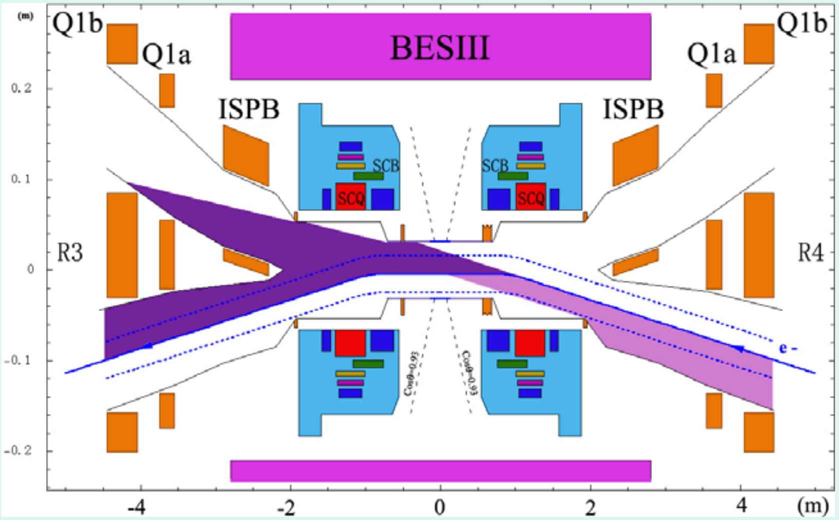
Masks in the vacuum chamber along storage ring are designed to prevent lost particles from hitting the IR. Simulation indicates these masks work effectively.

A tube type masks made of 2.5cm uranium are designed between the SC magnet of IR and the inner wall of the MDC to protect the detectors from the backgrounds.

Higher IR vacuum is important to reduce lost particle backgrounds.

Vacuum chamber in the central IR

SR fans --- SR mode



SR fans of SR Mode

The SR mode will be operated at energy of 2.5GeV. The maximum beam current is 250mA.

Ec<2.3keV

Since BEPCII will be operated with colliding and SR modes, which have different synchrotron radiation sources and synchrotron radiation fan distributions, the situation of SR must be studied separately.

Vacuum chamber in the central IR

Temperature control

SR power and HOM are unavoidable and cause heat problem.

damage devices, bring unstable to electronic components.

Be pipe, designed by detector people.

Heat source: SR power, HOM, heat spread from other pipes.

The temperature vibration of Be pipe should be controlled within 2 degree according to requirement of the detector. The Be pipe is designed as double-wall structure with 1.4 mm gap of cooling channel.

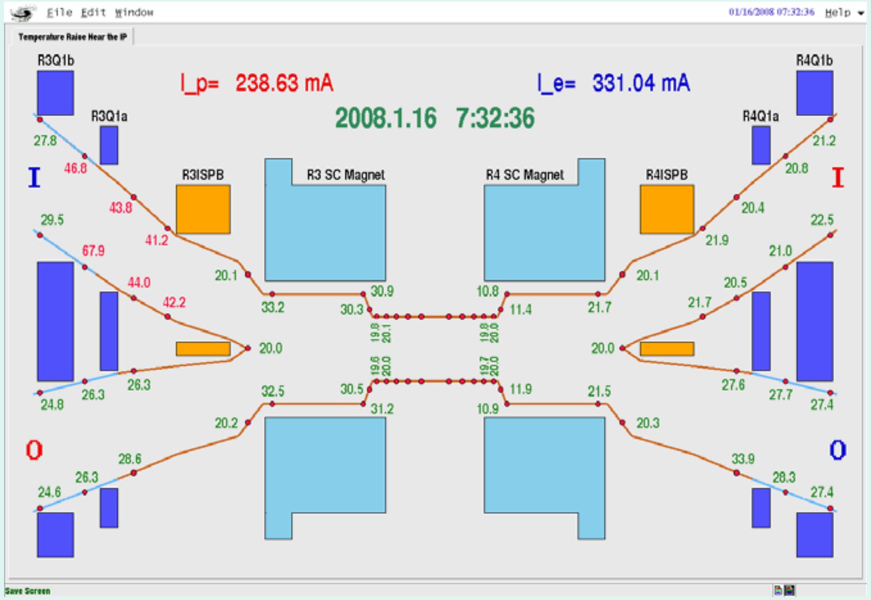
Other vacuum chamber in the IR, designed by accelerator people.

Heat source: SR power, HOM.

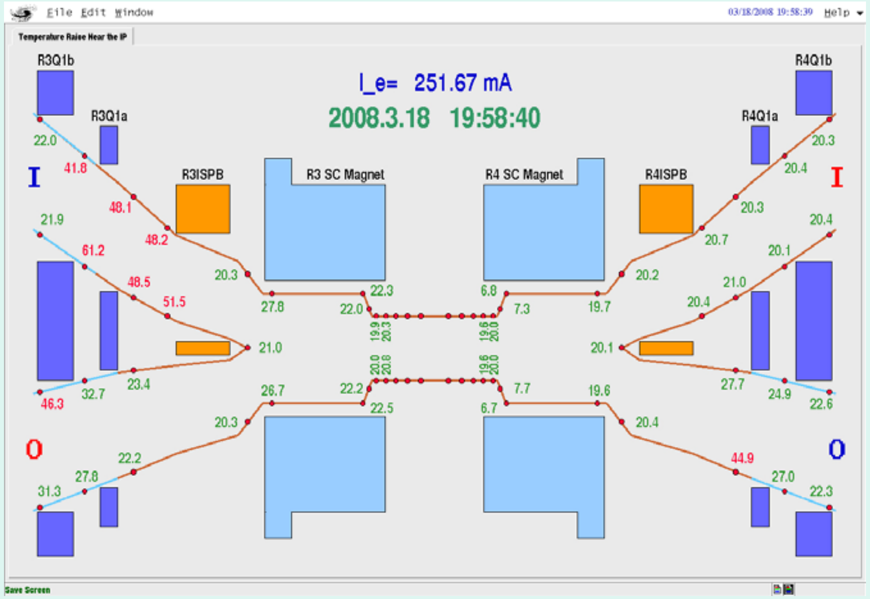
Water cooling structure are designed in the beam pipe 0.5~0.7m from the IP, the crotch chamber, the beam pipe 3.0~4.0m from the IP and all the bellows to avoid the heat problem in these region .

Vacuum chamber in the central IR

Temperature control



Colliding mode



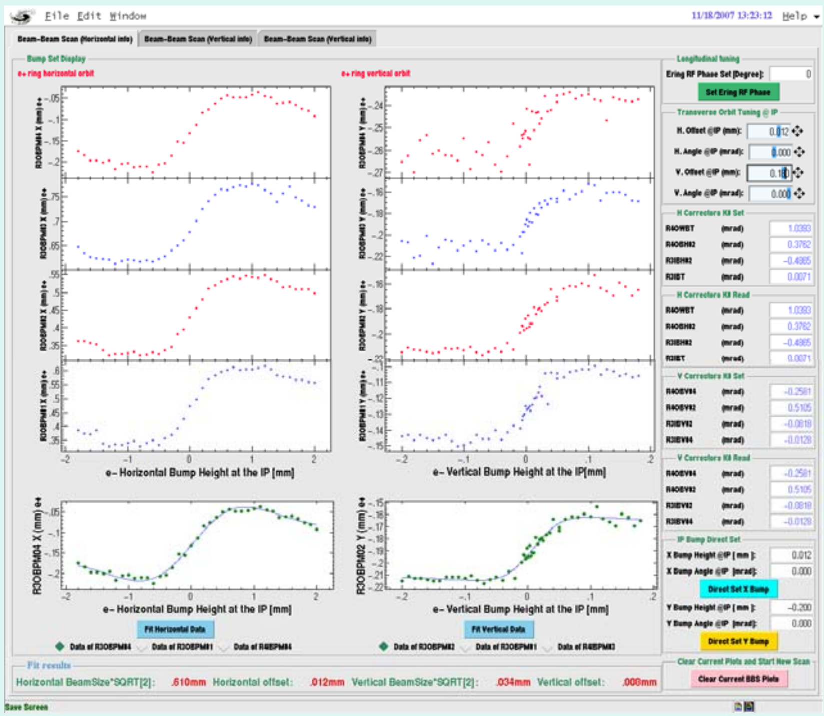
SR mode

There are 132 thermocouples in the IR to monitor the temperature raise and SR fans behavior.

The temperatures of vacuum chambers were controlled effectively. The temperature of some region are higher than normal level because there are no water cooling due to fabrication problem. It will be fixed this summer.

Collision tuning monitors

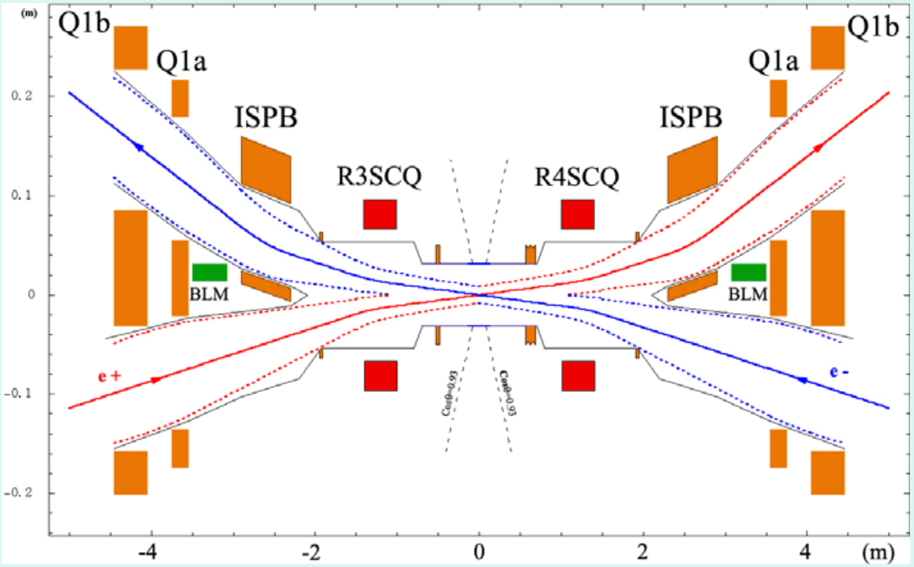
The beam-beam deflection technique is adopted in the BEPCII to find and maintain the collision conditions.

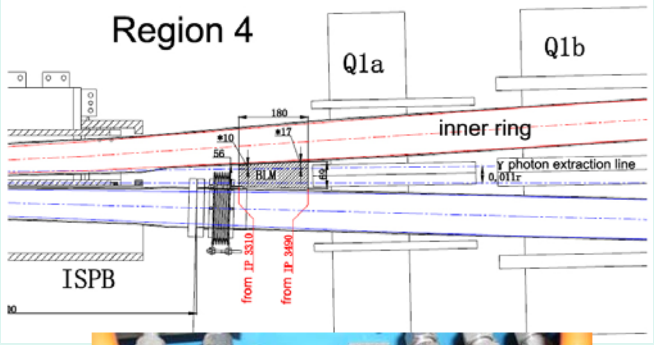


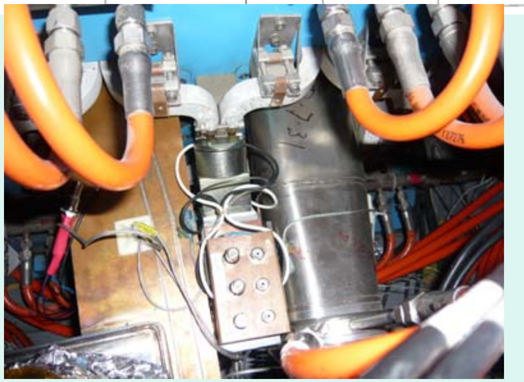
For the consideration of phase advance and beta function, the BPMs between Q1a and Q1b are set to measure horizontal beam-beam kicker angle. The BPMs on the crotch beam pipe are set to measure vertical beam-beam kicker angle.

Collision tuning monitors

A pair of Cherenkov luminosity detectors which measure the radiative Bhabha photons are installed to monitor positron and electron beam respectively.



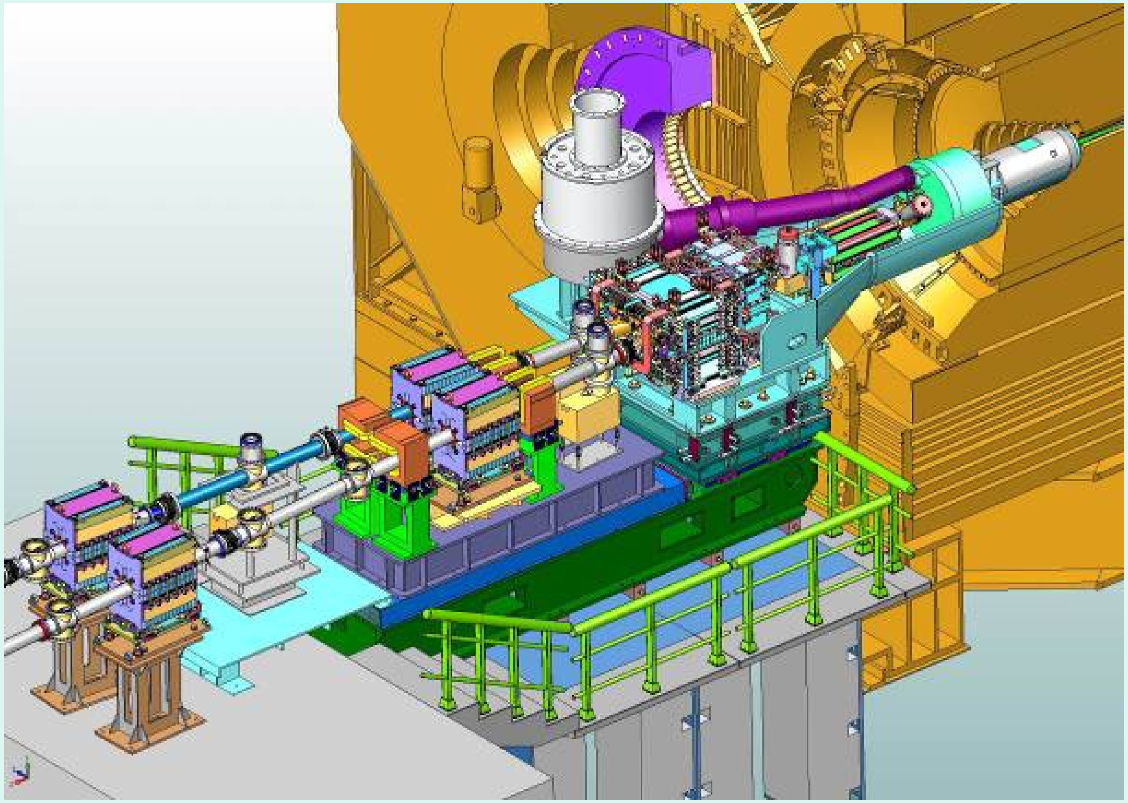




$e^+ e^- \rightarrow e^+ e^- \gamma$

They worked well during the last collision tuning operation.

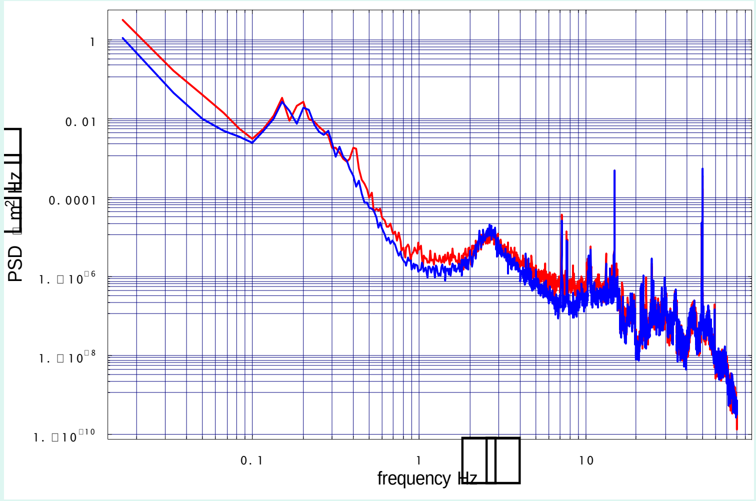
IR supporting system

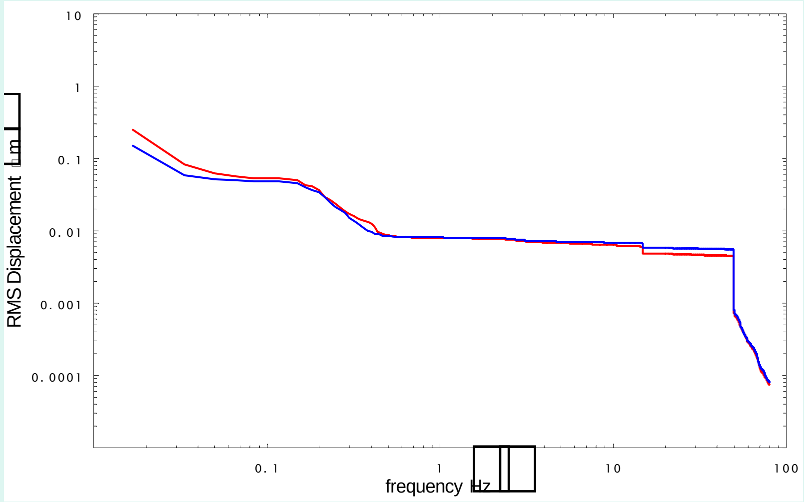


The SC cryostat, transfer line, valve box, ISPB, Q1a, Q1b are supported by a movable stage. The cantilever girder is connected with a movable stage which can move along the beam line by approximately 3 m. With this motion the SC magnets can be pulled out and pushed into the detector.

IR supporting system

The vibrations of magnetic elements due to the ground motion would cause the distortion of the beam orbits and effect on the beam performance (σ_y=5μm at the IP). The measurements of ground motion in IR was carried out.



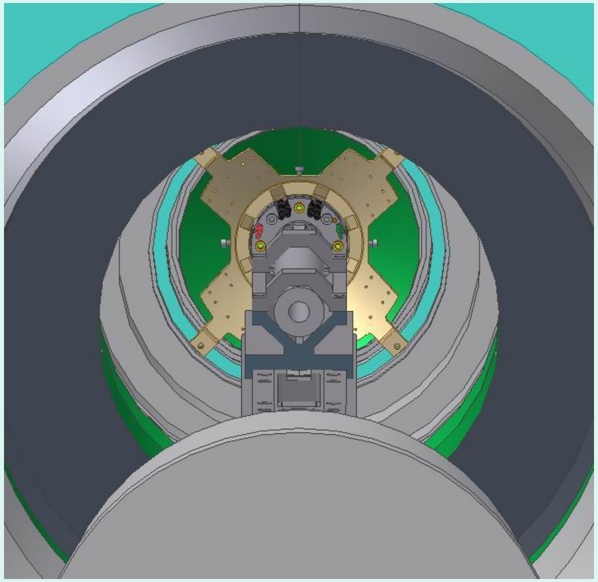


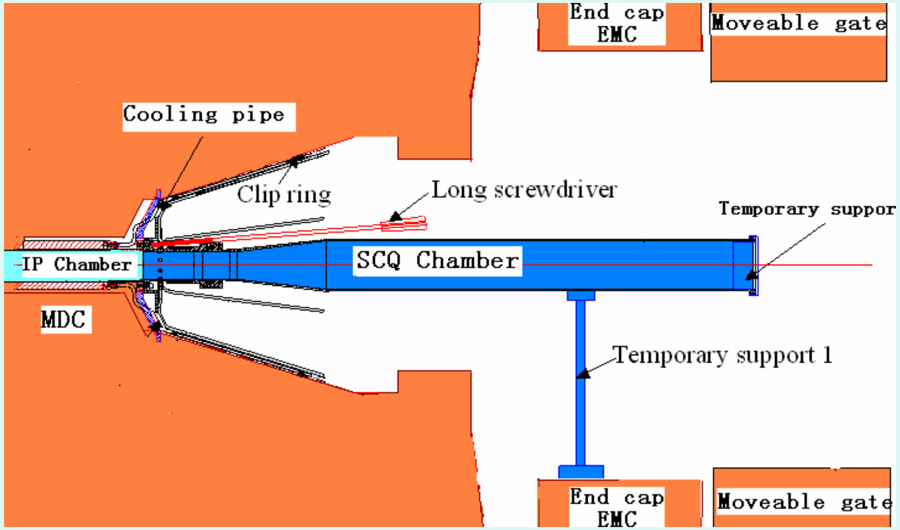
The noise level of IR is so low that the vertical vibration amplitude is 10nm at the frequency range above 1Hz. The inherence frequencies of supporting system of interaction region have avoided meeting all the noise frequencies which have been found till now.

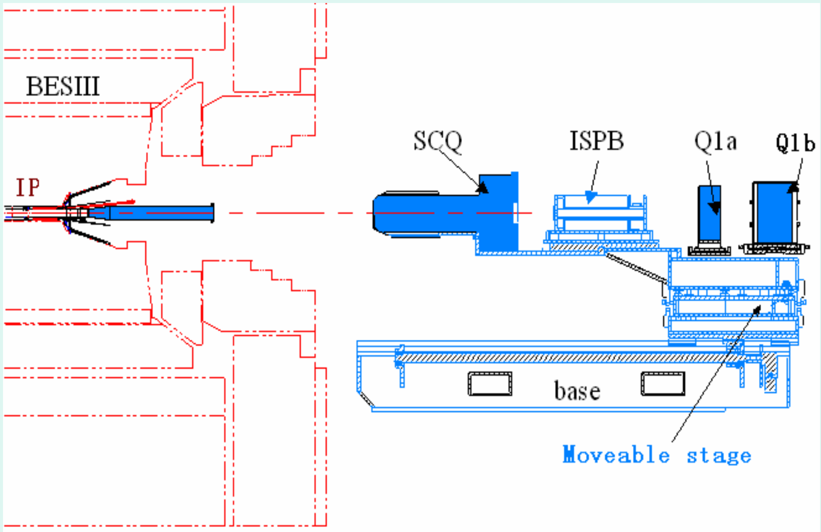
Integration procedure of IR

- Installing the central IP chamber and fixed it.
- Connecting the flanges between the IP chamber and SCQ chamber.
- Pushing the SC magnet into its final position.
- Connecting the flanges between the SCQ chamber and crotch section.
- Installing ISPB, Q1a, Q1b……

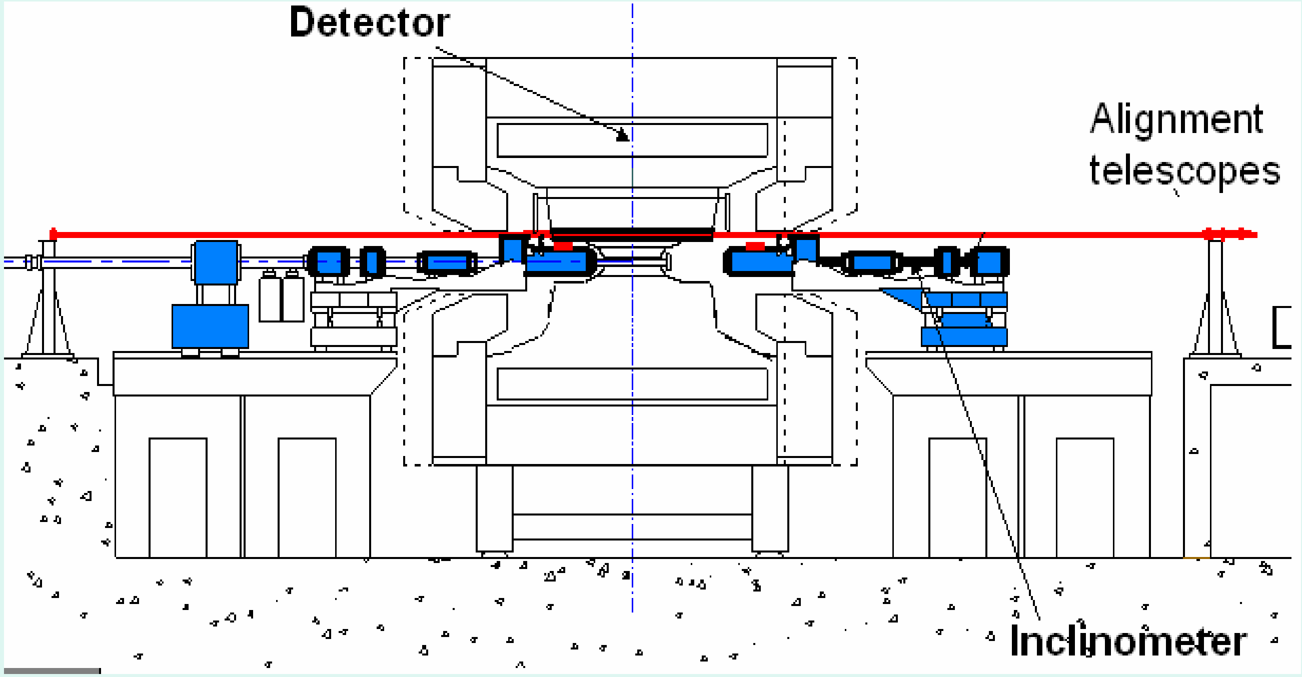
Cable, Cooling pipe, etc. should be paid more attention.







Alignment of two SC magnets



The alignment position and angle of the SC magnet can be adjusted by a mechanism installed on the movable stage. Four hair cross targets on the surface of each cryostat are used to align the left and right SC magnets. On each endplate of the main drift chamber of detector, two quartz windows will be installed. They allow the surveyors to look through the left and the right pair of targets.

Summary

All the components of the IR have been fabricated successfully. During the commissioning of BEPCII the operation experience show that the IR components have excellent performance and meet the design requirements.

The detector will be rolled into the interaction point this summer. Coupling compensation, background issues, radiation dose, etc. will bring new challenges for the commissioning of the BEPCII.

Thanks !